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Digital C3 Systems: Potential for Sharing Lessons Learned Across Services

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This research project investigated digital command, control, and communications (C3) systems of the U.S. military services to find information which could be used to help integrate U.S. Army digital C3 systems into digital units. The first part of the project identified key elements of U.S. Army digital systems and used these elements to identify similar systems in the U.S. Navy, U.S. Air Force, U.S. Marine Corps, and civilian services such as police, fire or emergency services. Once similarities were identified, the next step was to collect information on lessons learned, best practices, training, and research which would be relevant to U.S. Army digital systems. The results found that few digital C3 were similar to U.S. Army systems, and most are still under development. The only systems which had close similarities with U.S. Army digital systems were tactical-level systems used by the U.S. Marine Corps. Consequently, agreements have been made to share research and development products between the U.S. Army and the U.S. Marine Corps.

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DIGITAL C3 SYSTEMS: POTENTIAL FOR SHARING LESSONS LEARNED ACROSS SERVICES

Introduction

The U.S. Army has incorporated digital Command, Control, and Communications (C3) systems into its operational formations. Other services have similar systems and share similar research, development, and fielding challenges with U.S. Army digital systems. Although digital systems used by the Air Force and Navy are quite different from Army systems, key digital concepts may be the same. If so, the opportunity exists to leverage lessons learned from these systems to speed the maturation of Army digitization.

The purpose of this research was to identify systems from other services which are similar to digitization, and then identify lessons learned and best practices from other digitization programs which could be incorporated into the U.S. Army digitization effort to enhance digital training and evaluation. What we were primarily looking for were systems similar enough to U.S. Army digital systems that information could be used to improve U.S. Army digitization. We were specifically interested in information on digital skills, task analyses, evaluation methods, and automated evaluation tools.

This study investigated digital C3 systems in other military services, including the U.S. Air Force, U.S. Navy, U.S. Marine Corps, and Joint Command Centers, as well as relevant civilian organizations, such as police, fire, or emergency management to identify similarities between these systems and U.S. Army digital systems. The following section provides some background on digital C3 systems, focusing on U.S. Army digitization. Later sections describe how this research was conducted and the findings, and discusses the relevance of the findings to U.S. Army digitization.

Background

The U.S. Army has introduced a system of networked C3 computer systems, termed digital systems, into combat formations and Tactical Operations Centers (TOC) at all echelons. The goals of digitization are to increase combat capabilities by increasing situation awareness (SA) at all echelons and increasing operations tempo.

These networked computer systems automate many of the C3 functions previously accomplished manually, such as coordinating planning guidance, distributing orders and battlefield graphics, and reporting. They also increase safety by reducing the chances of fratricide (or "blue on blue") incidents. Information on the tactical situation can be distributed over the network from command centers down to the lowest-level combat formations, who can use the information to gain a tactical advantage. Combat units who use digital systems are expected to maintain better SA and to plan and execute operations more quickly than non-digital units (Barnett, Meliza, & McCluskey, 2001).

Digitization also fosters communication and coordination among staff sections during operations planning phases. Planning products can be posted to the network and accessed by staff officers as they conduct their operations planning. This ensures plans employ the most

recent information and helps integrate products from each of the Battlefield Operating Systems (BOS) into a cohesive whole.

Digitization serves as a decision-support system for combat commanders. It helps them visualize the battlespace and presents needed information in a spatially realistic and temporally dynamic format, thus fostering the commander's SA.

In addition, digitization serves to improve the SA of combat units. Units equipped with digital systems can view the same spatially realistic, near real-time displays available to commanders. This provides both commanders and Soldiers with a "Common Operating Picture" (COP) which allows them to develop a shared mental model of the battlefield situation. This shared mental model in itself improves communications since a commonality of information reduces the need for elaborate explanations of tasks to be performed. With the same information as commanders, Soldiers can readily understand and even anticipate orders.

Digitization enhances communications as well. Traditionally, communications have been handled by voice radio, which tends to be a serial process, that is, only a single person can talk on a given channel at one time. However, digital messages flow in both directions and in all directions near simultaneously, so that communications delays common to radio are significantly reduced.

To be able to exploit the advantages of digitization, units must develop considerable expertise with digital systems. Often, substantial effort must be expended to learn precursor skills before leaders and Soldiers can develop digital skills that give them a tactical advantage on the battlefield. A study by Leibrecht, Lockaby, and Meliza (2003) found that the job of a unit can become more complex as the unit attempts to make greater use of digitization.

Method

The research progressed in several stages. The first stage was to identify key elements of digitization which could be used to compare other systems to see how close they are to U.S. Army digital systems. This was done by first making a list of how certain combat tasks are performed by non-digital units and then describing how digital units performed the same tasks. These were primarily communication, planning, and execution tasks typical of those conducted at Brigade and below using the Force XXI Battle Command, Brigade and Below (FBCB2) system. The task descriptions were compared to identify what differentiated digital from non-digital task completion. These differences were then used as key elements of digitization.

As the research progressed, it became clear that the various digital systems perform different tasks, particularly at different echelons. Therefore, it was decided to identify common echelons among the services and only compare digital systems at the same echelon.

Next, a search was conducted to identify C3 systems used by the U.S. Air Force, U. S. Navy, and Joint Command Centers which might be similar to U.S. Army digital systems. The search was expanded to include civil government applications which may be similar to digitization, such as police, fire, or emergency services. For each agency, we looked for systems

that were similar to both upper echelon and lower echelon digital systems. Each C3 system was examined to determine how similar they are to U.S. Army digital systems.

Experts and researchers for various C3 systems were contacted and asked for data relevant to skills, best practices, or evaluating skill acquisition with these systems. The organizations contacted included the Naval Air Warfare Training Systems Division (NAVAIR TSD), the Air Force Research Laboratory Human Effectiveness Directorate (AFRL/HEA), and the United States Marine Corps (USMC) Training Systems Division. Information was also accessed from public sources, including research reference libraries and the Internet. The information obtained from these sources was reviewed to see what could be incorporated into the U.S. Army digitization program.

Results

Key Elements of Digitization

An analysis of the differences between how non-digital and digital units perform combat tasks uncovered several elements unique to digital units which could be considered the key elements of digitization. The most obvious is that much of the C3 information in a digital unit is transmitted as digital data over a network. However, in addition to other C3 functions, including planning and reporting functions, are either automation-aided or fully automated. Further, digital units typically have graphic displays of the battlespace which foster a shared SA among units; the COP.

Therefore, for the purposes of this research, a digital system is one which has (1) a digital data network where data is in digital form, and distributed over a network so that it can be transmitted, modified, shared, and displayed more easily; (2) digital C3 functions which includes automated planning and reporting tools; and (3) a method for displaying a COP where C3 data is digitally posted on the network and SA data is available to all echelons and units, both vertical and horizontal.

Echelon considerations. An analysis of automated C3 systems in the various services showed that even though the services strive towards a goal of a single, integrated C3 system, the nature of C3 at upper echelons is sufficiently different from lower echelons to require different systems. This is because different echelons have essentially different tasks. Upper echelons are more concerned with placing tactical units in an advantageous position to engage the enemy (known as maneuver), and also providing needed support for those units. Lower echelon units (tactical units) are those who engage the enemy directly, and are concerned with target acquisition and engagement, as well as survivability. Field Manual 3-0 (Department of the Army, 2001) defines the upper echelon as operational level, that is, responsible for the entire military operation, whereas the lower echelon units would be tactical level because they engage enemy units directly in close combat. According to Field Manual 3-0; "The operational-level headquarters sets the terms of battle and provides resources for tactical operations," whereas, tactical level is, "where friendly forces are in immediate contact and use direct and indirect fires to defeat or destroy enemy forces and to seize or retain ground. (Department of the Army, 2001).

In the U.S. Army this is illustrated by the use of FBCB2 at echelons below Brigade, and different systems above brigade which tend to focus on specific BOS's. In the U.S. Air Force,

tactical-level C3 is provided by an Airborne Warning and Control System (AWACS) or Airborne Battle Command and Control Center (ABCCC) aircraft; whereas theater- or operational-level C3 is provided by a ground-based Air Operations Center (AOC). Naval air warfare has a tactical level, the aircraft "flight," or "strike package" but no real operational level. For U.S. Navy surface warfare, there is no real analog to tactical-level units since the smallest unit would be a single ship. Except for coastal patrol vessels, even the smallest ocean-going ships have crews of nearly a hundred (Department of the Navy, 2004). Also, the nature of surface warfare is to engage the enemy at a distance and not in close combat. Therefore, for the purposes of this research, naval surface warfare is not considered to have a 'lower echelon' in the same sense that land forces do. Table 1 shows how upper and lower echelons for the three services were differentiated for the purposes of this research.

Table 1. Distinction Between Upper and Lower Echelon Command and Control for the Three Services

Service	Upper Echelon	Lower Echelon
U.S. Army	Brigade and above	Below Brigade
U.S. Marine Corps	Brigade and above	Below Brigade
U.S. Air Force	Theater/Operational level	Tactical level (aircraft flight)
U.S. Navy (surface warfare)	Fleet level	None
U.S. Navy (air warfare)	None	Tactical level (aircraft flight)

Because C3 is different for upper and lower echelons, digital C3 systems for these echelons were considered differently. In comparing systems across services, upper echelon systems were compared with other upper echelon systems, and lower echelon systems were compared with other lower echelon systems.

Similarity Between U.S. Army and Other Services Digital Systems

Joint systems. The principle tactical-level digitization-like system used by the air forces of all services is the Tactical Data Information Link (TADIL) (Federation of American Scientists, 2000). TADIL is not a hardware system but a data link structure that allows hardware from different systems and services to share information (U.S. Naval Academy, n.d.). TADIL might be considered an early form of digitization.

TADIL is used principally for air defense and connects ground radar systems, AWACS aircraft, fighter aircraft, and ground command centers. Information about enemy aircraft can be displayed on the radar screens and data terminals, allowing improved SA (Goodman, 2002) and a rudimentary COP. The most recent version is a joint data link used by all services called TADIL-J (known in the U.S. Navy as Link-16).

Systems that use TADIL are trained differently depending on the roles of the operators. Since TADIL-related systems are an integrated part of the aircraft avionics, pilots and aircrews are trained on these systems as part of their flying training, and practice during air defense exercises. On the other hand, the U.S. Air Force trains AWACS and ground-based battle management personnel through a training program which provides new officers an orientation to

battle management theory. They learn how to employ the system through an apprenticeship program which may take two-to-three years to mature battle managers (Miller, 1997).

There are some slight similarities between TADIL and U.S. Army systems tactical level digital systems. They both use data links and they both have SA displays, although the displays show different information. However, TADIL was originally designed for top-down control of air defense forces, and sharing information among tactical level units is a later innovation. Thus, the digital C3 functions, the second key element of digitization, are very different.

U.S. Air Force. The operational-level digital system used by the Air Force and other services air forces is the Theater Battle Management Core System (TBMCS), which is used to plan the theater air campaign and distribute the plan to operational forces (Zaharee, 2003). As the term "Core" in the name implies, TBMCS integrates information from other air campaign planning systems, such as the Contingency Theater Automated Planning System (CTAPS), the Wing Command and Control System (WCCS), and the Combat Intelligence System (CIS). It's output consists of Air Tasking Orders (ATO) and Airspace Control Orders (ACO). It is a system which is primarily designed for air campaign planning. Although it assists in air mission execution, this is mostly by sharing planning and intelligence information with AWACS.

TBMCS is a relatively new system which is in the process of being fielded. The system consists of three main components; flight status boards, an intranet which provides access to status and capabilities of squadrons on the intranet, and a map function (Nelson, 2001). TBMCS has slight similarities to the planning and logistics systems used by the U.S. Army on the upper Tactical Internet (TI), however, the similarities are fairly generic. Although TBMCS transmits information over a data link, the C3 functions are focused on air campaign planning and are very different from U.S. Army digital systems.

U.S. Navy. The U.S. Navy uses TADIL-J for tactical control of air defense forces (U.S. Naval Academy, n.d.). For naval forces other than aircraft, it is difficult to distinguish between "tactical" and "operational" levels when dealing with fleets of ships. The digital system the U.S. Navy is using for fleets is the Global Command and Control System – Maritime (GCCS-M) (Department of the Navy, 2002; Federation of American Scientists, n.d.; Naval Command and Control System Program Office, n.d.). GCCS-M operators attend a two-week training course that teaches the "capabilities, operations, and functions of the GCCS-M system." (Federation of American Scientists, n.d). This system has slight similarities with some upper-TI systems used by the U.S. Army. It was difficult to acquire information on the level of maturity of GCCS-M, but it seems to be in the process of being fielded. Unfortunately, little information could be found on this system which could be applied to U.S. Army digital systems.

The U.S. Navy plans to integrate their digital C3 systems with a program called FORCEnet (Zelibor, 2004, January-February). FORCEnet promises to link together ashore C3 systems with at sea systems to produce an integrated whole C3 system. The program is currently under development.

Upper echelon C3 in the U.S. Navy is more closely related to the U.S. Air Force than the U.S. Army. Since the U.S. Navy has no ground forces, there are few analogs between the U.S.

Navy and U.S. Army operations. Again, comparing the key elements of digitization, U.S. Navy C3 systems use data links and have SA displays, but the digital C3 functions are significantly different from those performed by U.S. Army systems. Therefore, similarities are more generic than specific.

U.S. Marine Corps. The USMC also uses TADIL-J for tactical control of air defense. However, for ground maneuver units the Marines have a system similar to FBCB2 which is called the Command and Control Personal Computer (C2PC) system. It is a software package used on a commercial personal computer (PC). C2PC training is available from the contractor and covers system operation but does not include tactical employment (Northrop Grumman IT, n.d.). However, the USMC does include C2PC employment as part of their Expeditionary Warfare School curriculum (Sherrie Jones, personal communication, 17 March 2004), a course for USMC company-grade officers.

Although C2PC has some differences, many of the functions are very similar to lower echelon U.S. Army digital systems, namely FBCB2. It shares information over a network, performs many of the same C3 functions as lower echelon U.S. Army systems, and has SA displays. Therefore, the system is similar enough to U.S. Army systems that sharing information among the services would be of benefit. Currently, some U.S. Army units are including C2PC in their TOCs.

The USMC is also developing a system for ground maneuver units similar to the U.S. Army's FBCB2. This is called the Data Automated Command Terminal (DACT) and is to be fielded in two versions, the mounted version for vehicles (M-DACT) and dismounted version (D-DACT) for infantry. Both M-DACT and D-DACT have considerable similarities with FBCB2.

Civilian agencies. Police, fire, and emergency management agencies use many information networks, but none that could be called digitization. Many agencies have information sharing systems, but they do not share information to all tactical units simultaneously or can be used to develop a COP. Some information sharing systems are nationwide, such as the National Crime Information System (NCIC), but they are more of a linked database than a true digital system (Hitt, 2000). Some police departments have Computer Aided Dispatch (CAD) to help assign police vehicles to calls, but the systems could not be considered to promote a COP. None of the civilian systems analyzed had sufficient similarity with U.S. Army digitization to warrant further investigation at this time.

Summary of similarities. Unfortunately, few of the observed systems had much in common with U.S. Army digital systems. Most upper-TI systems are alike only in generic terms, in that they are connected by data links, and some use SA displays, but their purpose and operation are different enough from U.S. Army systems that any tactics, techniques, or procedures (TTP) developed for one system would have little value to another. Table 2 summarizes the level of commonality between the systems investigated and U.S. Army digital systems.

Likewise, many services lower-TI systems have only generic similarities with U.S. Army systems. Although the TADIL-J system has some similarity with FBCB2, the differences

between air and ground combat are enough to make any TTPs developed for TADIL-J of little use for FBCB2.

Table 2. Digital Systems Similar to U.S. Army Systems

System	Service	Similarity to U.S. Army System
TADIL-J/Link-16	USAF, Navy, Marines	Slight similarities with FBCB2
TBMCS	USAF, Navy, Marines	Slight similarities with Upper-TI Systems
GCCS-M	Navy	Slight similarities with Upper-TI Systems
C2PC	Army, Marines	Many similarities with FBCB2
DACT	Marines	Many similarities with FBCB2
Various	Civilian agencies	No similarities with digital systems

On the other hand, the systems used by the USMC for ground combat, C2PC and DACT, are similar enough in purpose and operation that TTPs and training strategies developed for these systems could be applied to FBCB2.

Potentially Useful Digital Information from Other Services

Tactics, tips and procedures (TTP). The only systems similar enough to U.S. Army digital systems for TTPs to be useful are C2PC and DACT used by the USMC. Unfortunately, DACT is currently under development and, as yet, has no TTPs. Although fielded, C2PC is still fairly new. None of the sources contacted knew of any existing TTPs for C2PC.

Digital skills. Outside of the U.S. Army, little investigation has been done into skills needed to effectively employ digital systems. The U.S. Air Force is developing "Mission Essential Competencies" (MEC) which could provide good information to help understand digital skills and skill development. In 2002 the AFRL/HEA began developing MECs, which comprise the knowledge, skills, and experiences required for successful mission completion (Bennett, 2002, Winter/Spring). MECs relating to fighter-AWACS operation or those for command centers might be relevant to U.S. Army digital systems. Unfortunately, at the current time these MECs are still under development (W. Bickley, personal communication, March 12, 2004).

Training. The training for most digital systems consists of classroom or on-the-job training. Classroom training typically trains users to operate system controls and read displays, but does not include how to best employ digital systems. Barnett, Meliza, and McCluskey (2001) point out that training to use digital systems is more than being able to turn them on and operate the controls, but also includes learning to employ the systems to gain a tactical advantage. Most of the services train digital systems by providing classes which explain how to operate the system, perform tasks, and use system tools. Few training programs provide guidance on how to best employ the system or what skills are needed to maximize the usefulness of the system. At the present time, most training programs teach operation, but not employment skills.

In the USMC, C2PC training is available from the contractor and covers system operation but does not include tactical employment (Northrop Grumman IT, n.d.). However, the USMC

does include C2PC employment as part of their Expeditionary Warfare School curriculum (Sherrie Jones, personal communication, March 17, 2004), a course for USMC company-grade officers.

Research. This study could find no specific research conducted by the other services which would be relevant to U.S. Army digital systems. The research and development (R&D) efforts of other services tend to focus on different areas than the U.S. Army's R&D programs. However, some research with these systems is generic enough to be generalized to U.S. Army systems, particularly in the areas of SA and team work. The U.S. Air Force and U.S. Navy have conducted research into SA (Golas, Montag & Hottenstein, 1996, for example), team operations, and decision making which could be generalized to U.S. Army digital operations. Most of this research is available in open sources.

Gentner, Cunningham, and Bennett (1998) discuss developing a taxonomy of measures of performance (MOP) and measures of effectiveness (MOE) for U.S. Air Force aircrews. Although the taxonomy itself is geared to aircrews and is not relevant to ground combat units, the method they used to develop the MOPs and MOEs might be helpful in developing such measures for U.S. Army digitization.

Also, the U.S. Air Force's development of MECs could be useful in understanding how people employ digital systems. At the time of this report, the MECs for AWACS, which would be the closest to digital systems used by the U.S. Army, are still under development.

Discussion

There are two major difficulties of finding "best practices" and similar information from other services digital systems and applying them to U.S. Army systems. The first is that most digital systems are so new that useful information, such as best practices, TTPs, training programs, and skills research, is still under development. Digitization and digital systems are evolving rapidly. New uses are being found for digital systems almost daily and doctrine is in a state of change. At this point, the optimum employment of digital systems has not been developed, therefore it is difficult to determine the best way to reach a goal when the goals are unclear. Similarly, it is difficult to design a training approach when there are no training objectives.

The second is that there is not enough commonality between many of the systems used by other services and U.S. Army systems to be able to generalize from one service to another. Trying to generalize between two digital systems which have minimal commonality of purpose may not yield anything that can be used. Information which is abstract enough to apply to both systems may be too abstract to be useful. For example, the TADIL-J network used to direct fighter aircraft helps pilots develop SA of the battlespace. Similarly, the U.S. Army uses FBCB2 to foster SA for leaders of maneuver units. However, the differences between defensive counter-air missions and ground combat means that the similarities can be no more concrete than "improves SA." Thus, such information may be generically useful, but provide few specific techniques that can be generalized between systems.

The one area of commonality this study found is between digital systems used by U.S. Army and USMC ground forces. These forces are doctrinally and organizationally similar

enough that digital systems used by each are very similar, and the training and skills needed to employ these systems are also similar. This is an area where research and information could be shared to the benefit of both services. To this end, the U.S. Army Research Institute (ARI) has begun sharing information and research products with USMC organizations involved in digital training.

Since the requirements for digital systems for the U.S. Army and USMC are very similar, a common system for the two services could be very useful. In fact, such commonality is being addressed. The Joint Requirements Oversight Council of the Joint Staff has identified the U.S. Army as the lead for "Joint Blue Force Situation Awareness" (JBFSA) (Joint Requirements Oversight Council, 2003). In addition, Headquarters, USMC is coordinating with the U.S. Army on JBFSA (USMC BFSA Coordination, n.d.).

Challenges in Conducting this Research

Information on digital systems was sometimes difficult to acquire. There are several reasons for this. For one, the differences in organization of the services make it difficult to know what organization would have information on a particular system. Also, as mentioned, digital systems are in the process of being fielded in most services, and information about them is not generally available, even within a service. The information that is available is often still being analyzed, and organizations are understandably reluctant to share un-verified data.

Ironically, information on digital systems was more readily available on Internet web pages and reference documents than from individuals. It was often challenging to identify which individuals had needed information and then contact them. The current operating tempo of the military keeps key individuals in constant state of task saturation and consequently difficult to contact. On the other hand, military organizations and contractors will often post background information on their web sites which can be a boon to researchers seeking basic information about their systems.

Conclusion

Although all of the services are fielding digital C3 systems, there is considerable variation among the systems. This is partly due to the different uses the services have for C3 systems, and partly due to the services developing their systems independently. The need for a common digital C3 architecture is becoming apparent, and is being addressed at the joint level.

It is clear that services that share common operating environment, such as ground forces or air forces, should also share a common digital C3 system. Commonality of systems reduces the logistics burden and increases coordination. The air forces already share a common digital framework for the defensive counter-air mission, namely TADIL-J. The future promises to have a similar architecture, if not a common system, for ground forces.

Although many digital systems are fielded, most have not matured to the point where doctrine about how they can best be employed is fully developed. In many cases, no one yet knows the full capabilities of digital C3 systems. It is not possible to share "best practices" and lessons learned among services because they have not yet been sufficiently developed.

However, hopefully the services will be able to share this information as digital C3 systems move towards commonality.

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APPENDIX A

Acronyms

ABCCC	Airborne Command and Control Center
ACO	Airspace Control Order
AFATDS	Advanced Field Artillery Tactical Data System
AFRL/HEA	U.S. Air Force Research Laboratory/Human Effectiveness Directorate
ARI	U.S. Army Research Institute
AOC	Air Operations Center
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System.
BOS	Battlefield Operating System
C2PC	Command and Control Personal Computer
C3	Command, Control, and Communications
CAD	Computer Aided Dispatch
CIS	Combat Intelligence System
COP	Common Operational Picture
CTAPS	Contingency Theater Automated Planning System
DACT	Data Automated Command Terminal
D-DACT	Dismounted Data Automated Command Terminal
FBCB2	Force XXI Battle Command, Brigade and Below
GCCS-M	Global Command and Control System-Maritime
JBFSA	Joint Blue Force Situation Awareness
M-DACT	Mounted Data Automated Command Terminal
MEC	Mission Essential Competencies
MOE	Measures of Effectiveness
MOP	Measures of Performance
NAVAIRTSD	Naval Air Warfare Training Systems Division
NCIC	National Crime Information Center
PC	Personal Computer
R&D	Research and Development
SA	Situation Awareness
TADIL	Tactical Data Information Link
TADIL-J	Tactical Data Information Link-Joint
TBMCS	Theater Battle Management Core System
TI	Tactical Internet
TOC	Tactical Operations Center
TTP	Tactics, Techniques, and Procedures
USMC	United States Marine Corps